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A METHOD FOR ANALYZING MULTIPLE SPELL DURATION DATA.(U)  
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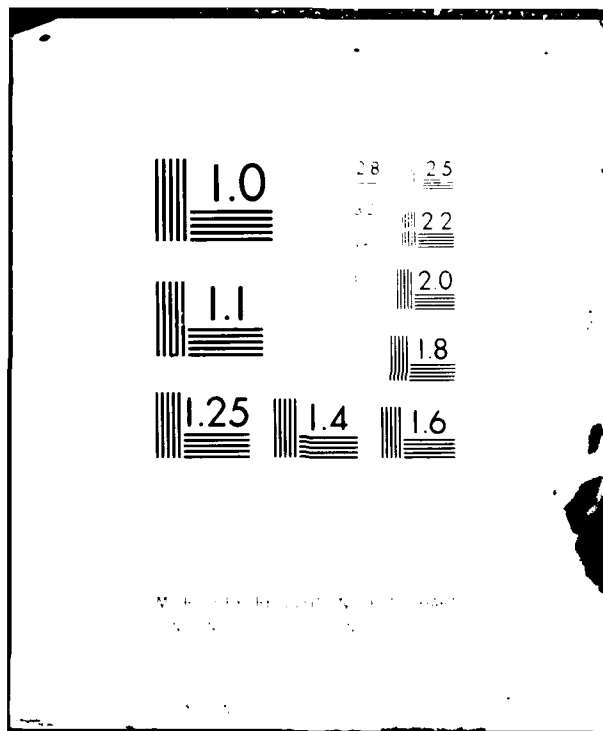
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# A METHOD FOR ANALYZING MULTIPLE SPELL DURATION DATA

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# A METHOD FOR ANALYZING MULTIPLE SPELL DURATION DATA

By

Philip Lurie, R. P. Trost and Edward Berger

## I. INTRODUCTION

In recent years many interesting papers in economics have been written on the general subject of analyzing duration data. This is especially true in the fields of human fertility and labor economics. For example, Flinn and Heckman (1981), Heckman and Borjas (1980), Kiefer and Neumann (1981), and Lancaster and Nickell (1980) study either employment or unemployment duration data. In similar papers, Mincer and Polachek (1974, 1978) and Mincer and Ofek (1980) use regression analysis to study unemployment duration data on married women. Gomez (1980) studies fertility duration data and Harris (1980) looks at infant mortality duration data. Fenn (1981) analyzes duration data on sickness absence and Kennan (1981) and Lancaster (1972) study strike duration data. In all of these papers the data are of the single spell type. That is, the analyst examines only one spell of history for each individual in the sample. The case of multiple spell data is more difficult, but two papers that look at the problem are Chamberlain (1981) and Heckman (1981b).

In general, the major emphasis in most of these papers is on estimating structural equations and correcting for heterogeneity bias<sup>1</sup>

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<sup>1</sup>Chamberlain (1980) looks at the heterogeneity problem in panel data, but not in the context of duration data.

As has been shown by Chamberlain (1981) and Heckman (1981a), uncorrected heterogeneity shows up in the data as apparent negative duration dependence, even though no duration dependence exists at the individual level. Consequently, much work in economics has been concerned with this issue of heterogeneity bias and its implications on testing for duration dependence (at the individual level).

While the heterogeneity bias and duration dependence issues are certainly worthwhile pursuits, none of the above mentioned papers offers a simple methodology to summarize the information contained in multiple spell data. The purpose of this paper is to fill that gap in the literature. Although we do not focus our attention on the heterogeneity problem, we do present a method that easily summarizes multiple spell data, even when the number of spells is large (we demonstrate our method with two examples, one with eight spells and another with twelve). Since very little work in economics has been done with multiple spell data, we feel that our method provides a useful tool for researchers. For example, employers may want to know how unemployment and employment spells of highly educated married women differ from those of less educated married women. Similarly, the military may want to compare the promotion histories of enlistees with high and low mental test scores. In the latter example, a spell is defined as the duration of an individual in a particular paygrade. As will be seen, our method offers a straightforward way of making the above comparisons.

The rest of the paper is divided into the following sections. In section II we present a general probability model that measures the impact of explanatory variables on: (1) the spell duration for each state (where "state" means, for example, employment or unemployment, and

(2) the probability of a transition from state  $i$  to state  $j$ ,  $i \neq j$ . In sections III and IV we illustrate our technique with two examples. Section V contains the conclusions.

## II. THE STOCHASTIC MODEL

In this section we present a stochastic model of state change and spell duration. The model we give is a semi-Markov model (or process). The estimation of the model involves estimating the distribution of time between states and the transition probabilities from one state to another. Both the probability of attaining a given state and the time in state are assumed to depend on a vector of exogenous variables and the previous state.

### 1. A General Semi-Markov Model

Suppose we observe individuals who can be in one of  $n+1$  states at any point in time. We shall assume that states  $1, 2, \dots, n$  are transient states, i.e., states which an individual can leave and to which he might possibly return, and that state  $n+1$  is an absorbing state, i.e., a state which cannot be left. For example, consider the managerial hierarchy in most major U.S. firms. An individual enters this hierarchy at some initial level or "rank," and moves up and down the hierarchy scale during his or her tenure with the firm. Eventually this individual will leave the firm (attrite) for one of several reasons--e.g., retirement, dismissal, job change. In this example then, the transient states are rank in the firm and the absorbing state is attrition.

Let  $Z_k$  be the random variable indicating the state at the  $k$ -th transition and let  $T_{Z_k}$  be the random variable referring to the time spent

in state  $Z_k$ . Denote

$$h_{ij}(t)dt = P\{Z_k=j, t < T_i < t + dt \mid Z_{k-1} = i\}.$$

Note that this quantity is assumed to be independent of  $k$ . Then, conditional on previously being in state  $i$ , the probability of making a transition into state  $j$  is clearly

$$\begin{aligned} p_{ij} &= \int_0^{\infty} h_{ij}(t)dt \\ &= P\{Z_k = j \mid Z_{k-1} = i\}. \end{aligned}$$

We assume that  $p_{ii} = 0$ , i.e., an individual cannot remain in any transient state indefinitely.

Given the transition from state  $i$  to state  $j$ , the probability density function (p.d.f.) of time spent in state  $i$  may be written as

$$\begin{aligned} q_{ij}(t)dt &= P\{t < T_i < t+dt \mid Z_k = j, Z_{k-1}=i\} \\ &= \frac{P\{t < T_i < t+dt, Z_k=j \mid Z_{k-1}=i\}}{P\{Z_k=j \mid Z_{k-1}=i\}} \\ &= \frac{h_{ij}(t)dt}{p_{ij}}. \end{aligned}$$

Thus we see that  $h_{ij}(t) = p_{ij}q_{ij}(t)$ . Let  $Q_{ij}$  be the complement of the cumulative distribution function (c.d.f.) corresponding to  $q_{ij}$ , i.e.,

$$Q_{ij}(t) = \int_t^{\infty} q_{ij}(x)dx.$$

The quantity which describes the probabilistic behavior of the multi-state system over time is



$$U_{ij}(t) = P\{\text{being in state } i \text{ at time } t \mid Z_0 = j\}.$$

An equation for  $U_{ij}(t)$  can easily be derived in terms of the aforementioned quantities. This is

$$\begin{aligned} U_{ij}(t) &= \delta_{ij} \sum_{k=1}^{n+1} P_{ik} Q_{ik}(t) + \sum_{k=1}^{n+1} \int_0^t h_{ik}(\tau) U_{kj}(t-\tau) d\tau \\ &= \delta_{ij} W_i(t) + \sum_{k=1}^{n+1} \int_0^t h_{ik}(\tau) U_{kj}(t-\tau) d\tau, \end{aligned} \quad (1)$$

where  $\delta_{ij} = 1$  if  $i=j$ , and equals 0 otherwise. We would like to be able to solve equation (1) in terms of the p's, q's, and o's. Theoretically, this can be obtained by taking Laplace transforms of both sides of equation (1), then solving for the Laplace transform of  $U_{ij}(t)$  and inverting it. However, in most cases, this procedure is numerically intractable. We therefore had to consider another approach.

Basically, what is involved is applying the trapezoidal rule to the integral in equation (1) and solving for  $U_{ij}(t)$  on a set of equally spaced points in time. The time points are denoted by  $t_i = \Delta t \cdot i$ ,  $0 \leq i \leq m$ , where  $\Delta t$  is the interval between time points and  $t_m$  is the farthest point in time to be considered. The solution for  $U(t) = \{U_{ij}(t)\}$  at any of these time points may be written as

$$\begin{aligned} U(t_1) &= [I - \frac{\Delta t}{2} H(0)]^{-1} \cdot [W(t_1) + \Delta t \sum_{k=1}^1 H(t_k) U(t_1 - t_k) \\ &\quad - \frac{\Delta t}{2} H(t_1) U(0)], \end{aligned} \quad (2)$$

where  $H(t) = \{h_{ij}(t)\}$  and  $W(t)$  is the matrix with elements  $W_i(t)$  along the diagonal and zeros elsewhere. Starting with  $U(0) = W(0) = I$ , equation (2) can be solved recursively on the remaining time points.

## 2. Choosing Functional Forms for $P_{ij}$ and $q_{ij}$ .

In the previous section we presented a general model of state change and length of time in state. To estimate this model allowing for the impact of exogenous variables, we need to choose particular functional forms for the transition probabilities  $p_{ij}$  and the density function of time in state  $q_{ij}$ . Hence, the model we propose is a special case of the general semi-Markov model discussed in the previous sub-section.

The way we propose to model  $p_{ij}$ , the probability of making a transition from state  $i$  to state  $j$ , is by a multinomial logit model. Specifically, we model  $p_{ij}$  as

$$\log \frac{p_{ij}}{p_{i,n+1}} = \alpha_{ij} Z, \quad (3)$$

where  $Z$  is a vector of explanatory variables, state  $n+1$  corresponds to the absorbing state, and  $\alpha_{ij}$  is a vector of unknown coefficients,  $i, j=1, \dots, n$ . This model may be estimated by the maximum likelihood method.

Given a specific state, the distribution of time spent in that state is modeled by the Cox regression model (see Cox (1972)), i.e.,

$$r_{ij}(t) = r_{oij}(t) e^{\beta'_{ij} X},$$

$$Q_{ij}(t) = e^{-\int_0^t r_{ij}(x) dx},$$

$$\text{and } q_{ij}(t) = r_{ij}(t) Q_{ij}(t), \quad (4)$$

where  $r_{ij}(t)$  is the hazard function corresponding to  $q_{ij}(t)$ ,  $\beta_{ij}$  is a vector of unknown coefficients,  $X$  is a vector of explanatory variables,

and  $r_{0ij}(t)$  is fixed and independent of  $X$ , but otherwise completely unspecified. The Cox model has the advantage of being able to handle censored observations. Methods for estimating  $\beta_{ij}$  and  $r_{0ij}(t)$  are described in Cox (1972). Using models (3) and (4) in conjunction then yields a model for  $h_{ij}(t) = p_{ij}q_{ij}(t)$ . This, in turn, allows us to estimate  $U_{ij}(t)$  given by equation (2).

### III. ANALYZING THE LIFETIME LABOR FORCE PARTICIPATION DECISIONS OF MARRIED WOMEN: AN ILLUSTRATION

In this and the following section we want to demonstrate our methodology with simple empirical illustrations. In this section we study the labor force decisions of married women. In the following section we study advancement and retention behavior of Navy enlistees.

In the course of her married lifetime, a woman will typically be in and out of the labor force for several extended periods. For example, she may work for the first few years of marriage; drop out for two or three years after the birth of her first child; return to work a second time; drop out a second time to have a second child; and finally return to work and remain in this state until retirement. Of course other schemes are possible. Some women may remain working their entire married life while others may permanently stay out of the labor force once their first child is born. A model of the sort described above is implied in the seminal work of Mincer [1962]. No doubt others have also proposed theoretical models that predict similar behavior. It is not our purpose in this section to present another such "dynamic" model of a woman's labor force decisions. Our main interest is to demonstrate how the

straightforward probability theory presented in Section II can be used to study these various lifetime models.

For example, consider the Heckman and Willis [1977] finding that labor force participation probabilities are "U-shaped." Here the term U-shaped means that over, say a five year period, most women will either be working all five years or not working all five years. This proposition is questioned by Mincer and Ofek [1980].

Mincer and Ofek [1979] argue that the U-shaped proposition should be tested with data covering a longer time period than the five year period [1967 to 1971] used by Heckman and Willis [1977]. The essence of the Mincer and Ofek [1979] point is that once a married woman starts to work, she tends to remain in the labor force for several years. If this is the case, we would expect to observe women working for several years, dropping out of the labor force for several years, and then returning for several years, et cetera. This implies that the number of years a woman remains in each of the work or nonwork states is one relevant dependent variable of interest. While the probit-logit type models cannot easily examine the impact of exogenous variables on the length of time women remain in each state, regression analysis is one easy way to do this. Mincer and Polachek [1974 and 1978] and Mincer and Ofek (1980) do analyze the length of time women remain out of the labor force with regression analysis. The findings in Mincer and Ofek [1980] suggest that education and various causes of work interruption such as health, child birth and the like, have a significant impact on the length of time a woman is unemployed. Using the method developed in section two of this paper, we can proceed in a manner suggested by Mincer and Ofek (1980) and examine

all unemployed and employed spells of married women in a single probability model.

We estimate the model of section three with the Parnes NLS data on 5,083 older women. These women were between the ages of 30 and 44 when first interviewed in 1967. The data set we use follows these women for the six year period beginning in 1967 and ending in 1972, and also gives previous work histories. We selected for our analysis those women who were married only once and responded to all the previous work history questions (variables 221 to 326 in the Parnes questionnaire). We were left with 1036 observations.

Table 1 shows the 1967 to 1972 work histories of these 1036 women. Note that 42 percent of these women either worked all six years ( $26.5\% = 275/1036$ ) or did not work all six years ( $15.5\% = 161/1036$ ). This is the U-shaped pattern found by Heckman and Willis [1977]. However, this does not tell the whole story, as Mincer and Ofek [1979] have pointed out. We need to look at their entire work histories, starting at the time of marriage. Since most of these women were married prior to 1967, this involves combining the information found in Table 1 with the information we have on their previous work history. Doing this, we were able to calculate the length of time each woman spent in each of the eight states defined in Table 2: w1, nw1, w2, nw2, w3, nw3, w4, nw4. The number of observations we have for each state are given in Table 3. Note that we have all 1036 observations in the "working for the first time" state (w1), since all these women were working at the time of marriage. However, since some of the observations in the w1 state are censored, we only have 926 observations in the nw1 state. An observation

TABLE 1: Employment Patterns of  
Married Women in the Parnes Older Women Data\*

67	68	69	70	71	72	Path	Number of Observations
1	1	1	1	1	1	1	275
1	1	1	1	1	0	2	29
1	1	1	1	0	1	3	17
1	1	1	1	0	0	4	14
1	1	1	0	1	1	5	37
1	1	1	0	1	0	6	4
1	1	1	0	0	1	7	5
1	1	1	0	0	0	8	25
1	1	0	1	1	1	9	26
1	1	0	1	1	0	10	2
1	1	0	1	0	1	11	5
1	1	0	1	0	0	12	5
1	1	0	0	1	1	13	3
1	1	0	0	1	0	14	2
1	1	0	0	0	1	15	2
1	1	0	0	0	0	16	27
1	0	1	1	1	1	17	39
1	0	1	1	1	0	18	7
1	0	1	1	0	1	19	4
1	0	1	1	0	0	20	5
1	0	1	0	1	1	21	8
1	0	1	0	1	0	22	4
1	0	1	0	0	1	23	2
1	0	1	0	0	0	24	6
1	0	0	1	1	1	25	16
1	0	0	1	1	0	26	1
1	0	0	1	0	1	27	2
1	0	0	1	0	0	28	4
1	0	0	0	1	1	29	2
1	0	0	0	1	0	30	2
1	0	0	0	0	1	31	5
1	0	0	0	0	0	32	41
0	1	1	1	1	1	33	41
0	1	1	1	1	0	34	5
0	1	1	1	0	1	35	7
0	1	1	1	0	0	36	7
0	1	1	0	1	1	37	3
0	1	1	0	1	0	38	1
0	1	1	0	0	1	39	1
0	1	1	0	0	0	40	6

TABLE 1 Continued

67	68	69	70	71	72	Path	Observations
0	1	0	1	1	1	41	3
0	1	0	1	1	0	42	4
0	1	0	1	0	1	43	1
0	1	0	1	0	0	44	0
0	1	0	0	1	1	45	0
0	1	0	0	1	0	46	1
0	1	0	0	0	1	47	4
0	1	0	0	0	0	48	13
0	0	1	1	1	1	49	31
0	0	1	1	1	0	50	7
0	0	1	1	0	1	51	6
0	0	1	1	0	0	52	3
0	0	1	0	1	1	53	0
0	0	1	0	1	0	54	1
0	0	1	0	0	1	55	1
0	0	1	0	0	0	56	12
0	0	0	1	1	1	57	30
0	0	0	1	1	0	58	9
0	0	0	1	0	1	59	7
0	0	0	1	0	0	60	17
0	0	0	0	1	1	61	10
0	0	0	0	1	0	62	4
0	0	0	0	0	1	63	14
0	0	0	0	0	0	64	<u>161</u>
TOTAL							1036

\*1 = working

0 = not working

TABLE 2: Definition of States for Married Women  
Who Were Working at the Beginning of the Sample Period

STATE	DEFINITION
w1	<u>Working</u> for the <u>first</u> time since marriage. [All women are assumed to start in state w1 when they are first married.]
nw1	<u>Not working</u> for the <u>first</u> time since marriage.
w2	<u>Working</u> for the <u>second</u> time since marriage.
nw2	<u>Not working</u> for the <u>second</u> time since marriage.
w3	<u>Working</u> for the <u>third</u> time since marriage.
nw3	<u>Not working</u> for the <u>third</u> time since marriage.
w4	<u>Working</u> for the <u>fourth</u> time since marriage.
nw4	<u>Not working</u> for the <u>fourth</u> time since marriage.



TABLE 3: The Number of Observations from the Parnes  
Older Women Data in Each of the Eight States (w1 to nw4)

<u>State</u>	<u>Number of Observations With Completed Spells</u>	<u>Number of Censored Observations</u>	<u>Total Number Of Observations</u>
w1	926	110	1036
nw1	826	100	926
w2	569	252	826
nw2	329	240	569
w3	126	203	329
nw3	43	83	126
w4	6	37	43
nw4	0	6	6

is termed "censored" if we do not observe a complete spell duration. For example, in our data set of 1036 women who were working immediately after marriage, 110 of them have never stopped working. Hence, for these 110 women we do not know the exact length of time they will remain in the w1 state. We only know how long they have been in state w1 as of 1972, but do not know how much longer they will continue in this state. For these 110 women then, we do not have a completed spell in state w1. As we pointed out in section II though, these censored observations are easily handled by the Cox regression technique.

Since our purpose in this section is to merely demonstrate the methodology developed in section II, we estimate a very simple model of the labor force participation decisions of married women. The only exogenous variables included in the analysis are education (EDUC) and a race dummy variable (DNWHITE) equal to 1 if the woman is nonwhite and zero otherwise.<sup>2</sup> No doubt more sophisticated specifications are possible, but they would not demonstrate our econometric methodology any better than the less complicated specification we choose.

The first step in using the technique of section II to estimate a model of the labor force participation decisions of married women is to estimate a series of several Cox regression models. Using our data base, this amounts to estimating seven<sup>3</sup> separate Cox regression equations. In the first regression, the dependent variable is the length of time each

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<sup>2</sup>One could easily specify a more general model. For example, one could include lagged variables (i.e., an individual's spell durations in previous periods) as right hand explanatory variables.

<sup>3</sup>Since all the observations in the eighth state (nw4) are censored, we could not estimate a Cox regression equation for state nw4.

woman remained in state w1. In the second regression, using only the subset of women who left state w1 (926 women in our case), the dependent variable is the length of time each woman remained in state nw1. A similar description holds for all the other states. In each case, the regression is only run on the subset of women who had a completed spell in the previous state.

The coefficients from the seven Cox regressions are reported in Table 4. The coefficients have the following interpretation. A positive coefficient for variable X in state  $S_j$  means that as X increases, the probability of leaving  $S_j$  increases in all time periods. A negative coefficient means that as X increases the probability of leaving  $S_j$  decreases. Hence, the positive coefficient on EDUC in state nw1 means that as a woman's education increases, the length of time she remains in state nw1 decreases. The negative sign on EDUC in state w2 means that as a woman's education increases, the length of time she remains in state w2 increases. The negative coefficient on DNONWHITE in state w1 indicates that non-white women remain in state w1 longer than white women. The positive coefficient on DNONWHITE in state nw2 indicates that non-whites remain in state nw2 a shorter time than whites. A similar interpretation holds for the rest of the coefficients presented in Table 4.

An obvious pattern emerges from Table 4. In all but one state (w1) we find that more educated women remain in the working states longer and in the non-working states shorter than less educated women. Also, we find that nonwhite women remain in the working states longer and in the non-working states shorter (with the exception of nw3) than white women. Although only a few coefficients are significant, the consistent pattern

TABLE 4: Cox Regression Coefficients for State w1 to w4  
(Dependent Variable = Length of Time in State)

Variable**	Coefficients in Each State Equation						
	w1	nw1	w2	nw2	w3	nw3	w4
EDUC	.00063 (.002)	.0268 (3.1)	-.032 (3.2)	.016 (.4)	-.046 (1.5)	.096 (1.9)	-.31 (2.0)
DNONWHITE***	-.243 (8.4)	.16 (3.1)	-.247 (4.8)	.059 (.15)	-.328 (1.6)	-.69 (1.3)	----
Number with Completed Spells	926	826	569	329	126	43	6
Number of Censored Observations	110	110	257	240	203	83	37
Number of Observations	1036	926	826	569	329	126	43

\* $X_1^2$  in parentheses

\*\*EDUC is the women's education in years. DNONWHITE is a dummy variable equal to 1 if the woman is not white and 0 otherwise.

\*\*\*DNONWHITE could not be included in state w4 because the entire sample of 37 observations were white.

of positive and negative coefficients is encouraging. More importantly, though, we feel the above simple model adequately demonstrates the feasibility of the econometric technique developed in section II.

To demonstrate the impact of race and education on the labor force participation of married women over time, we have evaluated<sup>4</sup>  $U_{ij}(t)$  in section II with the following combinations of exogenous variables: (1) EDUC=12 and DNONWHITE=0; (2) EDUC=16 and DNONWHITE=0; (3) EDUC=12 and DNONWHITE=1. Recall that  $U_{ij}(t)$  is the probability of being in state  $j$  at time  $t$  given that at time zero the individual was in state  $i$ . Comparing a specific  $U_{ij}(t)$  evaluated with the characteristics of group (1) to the same  $U_{ij}(t)$  evaluated with the characteristics of group (2) would therefore show the impact of education on the labor force participation decision of married women. A similar comparison of group (1) to group (3) would show the impact of race on labor force participation decisions. A simple example will help.

In Table 5 we show  $U_{ij}(18)$ ,  $i=1,2,\dots,8$ ;  $j=1,\dots,8$  when evaluated at the characteristics of group 1. The probabilities  $U_{ij}$  presented in Table 5 are arranged as follows. Row  $i$  gives the probabilities of being

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<sup>4</sup>The model presented in section II is actually more general than the model needed to analyze the lifetime labor force decisions of married women. In the more general model, an individual can move from a given state to one of several other states. Hence, the model has to attach probabilities to each of the possible state changes. In the labor force model though, once a woman is in a given state she only has one alternative state to move to. For example, if a woman is in the state "working for the first time" (state w1) the only state she can move to next is "not working for the first time" (state nw1). This greatly simplifies the model. If a woman moves from state w1 she must move to state nw1. There is no logit probability matrix to estimate. For a woman in state w1, the probability of moving to state nw1 is 1 and the probability of moving to all other states is 0. In the next section we present an example where the  $p_{ij}$ 's must be estimated.

TABLE 5: Probability of Being in State i  
Eighteen Years After Starting in State j.  
[Evaluated at the Characteristics of Group 1]

State j	State i							
	w1	nw1	w2	nw2	w3	nw3	w4	nw4
w1	.112	.107	.265	.230	.121	.050	.033	.080
nw1		.023	.265	.289	.168	.070	.048	.141
w2			.091	.284	.203	.089	.063	.272
nw2				.119	.209	.094	.070	.509
w3					.096	.048	.043	.818
nw3						.003	.005	.998
w4							.000	1.00
nw4								1.00

in each of the 8 possible states ("working for the first time since marriage" being the first state  $i=1$  and "not working for the fourth time since marriage" being the last state  $i=8$ ) after 18 years, given that the woman started in state 1 eighteen years ago. For example, the .112 in row 1, column 1 of Table 5 means that given a woman first entered state 1 eighteen years ago, the probability she is still in state 1 is .112. The .023 in row 2 column 2 of Table 5 means that given a woman entered state 2 eighteen years ago, the probability of her still being in state 2 is .023. A similar interpretation holds for the rest of the probabilities in Table 5.

Table 6 gives the probabilities  $U_{ij}(18)$  when evaluated at the characteristics of group 2, and Table 7 gives these same probabilities when evaluated at the characteristics of group 3. The interpretation of the probabilities presented in Tables 6 and 7 is the same as that for Table 5.

To demonstrate the continuous time aspect of our model, in Figures 1 to 4 we have graphed the probabilities of being in each of three states ( $w1$ ,  $nw1$  and  $w2$ ) as a function of time. In Figure 1 these three probability functions are graphed for women with a high school education ( $EDUC=12$ ) and are white ( $RACE=WHITE$ ). From Figure 1 we see that the probability a woman is in state  $w1$  (working for the first time since marriage) steadily declines over time. This decline is rather steep the first three years and levels off thereafter. This indicates that women are very likely to drop out of the labor force at least temporarily, soon after marriage. The probability that these women are in state  $nw1$  (not working for the first time since marriage) increases for the first three years of marriage, and declines thereafter. Finally, Figure 1 indicates

TABLE 6: Probability of Being in State j  
 Eighteen Years After Starting in State i.  
 [Evaluated at the Characteristics of Group 2]

State i	State j							
	w1	nw1	w2	nw2	w3	nw3	w4	nw4
w1	.112	.090	.294	.215	.139	.033	.033	.084
nw1		.015	.289	.268	.191	.046	.047	.146
w2			.121	.269	.235	.056	.059	.261
nw2				.104	.254	.060	.067	.515
w3					.143	.031	.040	.740
nw3						.000	.001	1.000
w4							.000	1.000
nw4								1.000



TABLE 7: Probability of Being in State j  
 Eighteen Years After Starting in State i.  
 [Evaluated at the characteristics of group 3]

state i	State							
	w1	nw1	w2	nw2	w3	nw3	w4	nw4
w1	.180	.090	.301	.186	.128	.059	.018	.037
nw1		.012	.319	.261	.201	.098	.031	.079
w2			.154	.270	.251	.132	.044	.150
nw2				.105	.294	.180	.064	.356
w3					.185	.153	.061	.604
nw3						.058	.028	.920
w4							.000	1.000
nw4								1.000

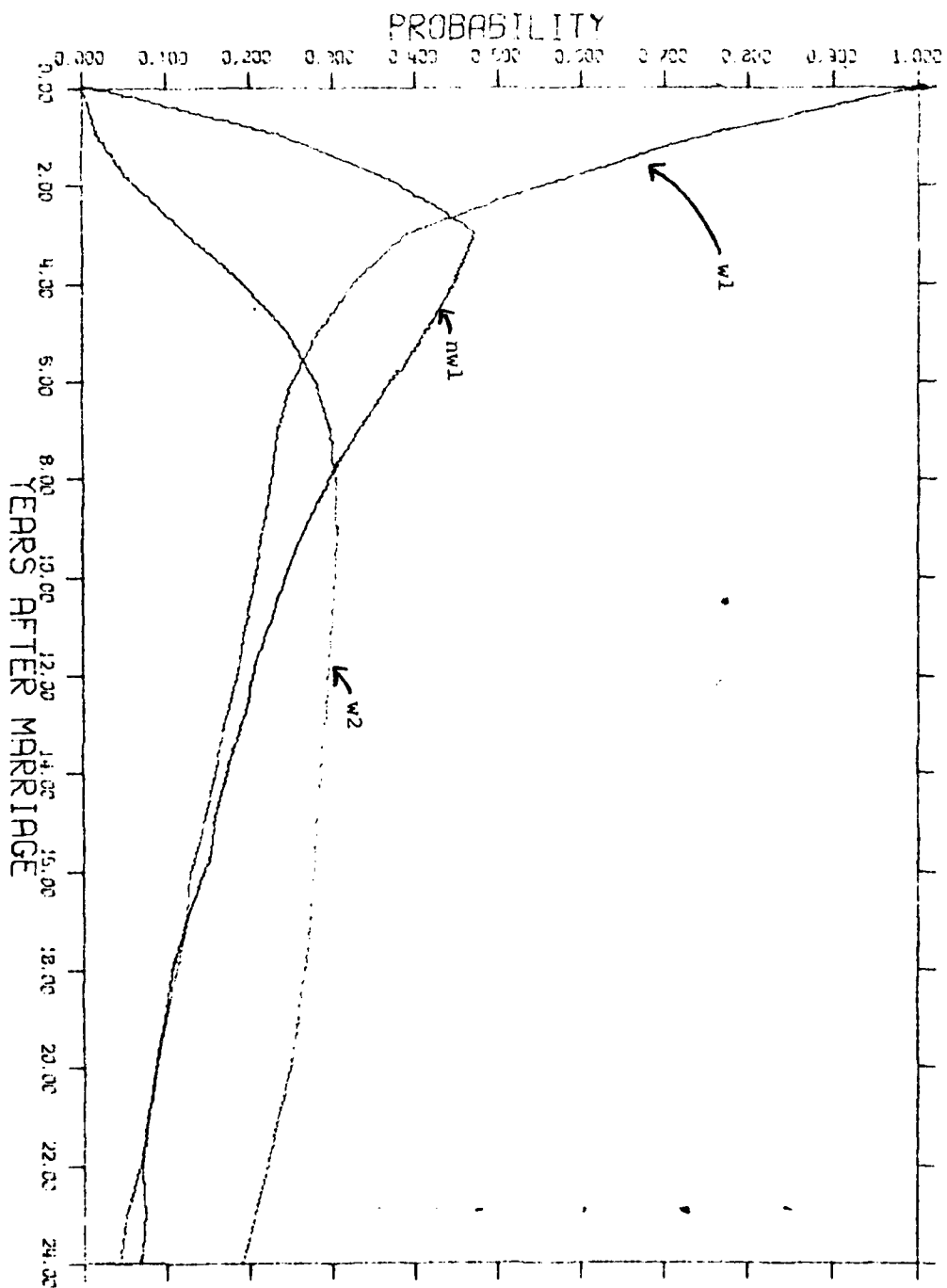


FIGURE 1  
EDUC=12 YRS, RACE=WHITE

FIGURE 1  
EDUC=12 YRS, RACE=WHITE

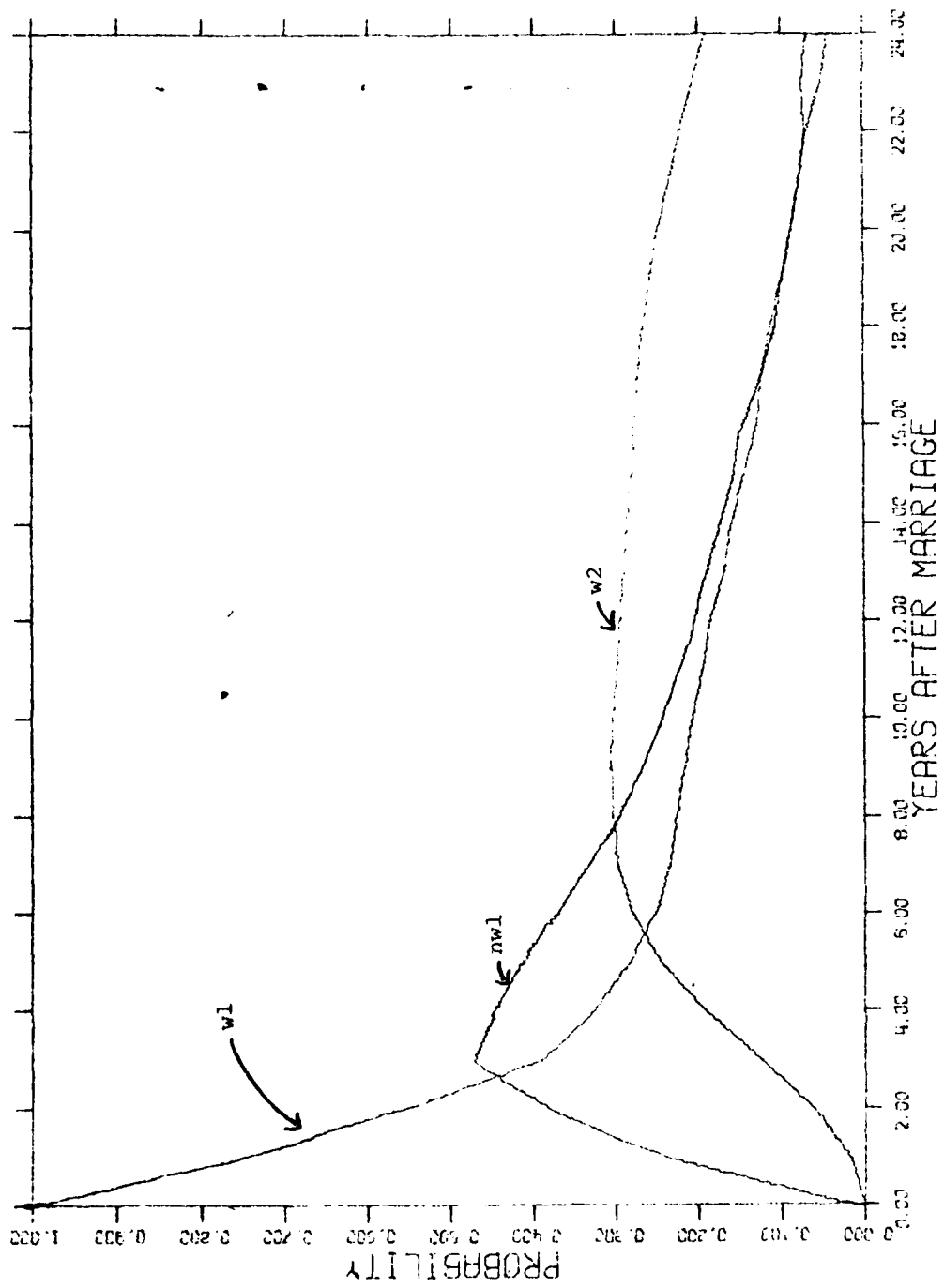


FIGURE 2

EDUC=12 YRS, RACE=BLACK

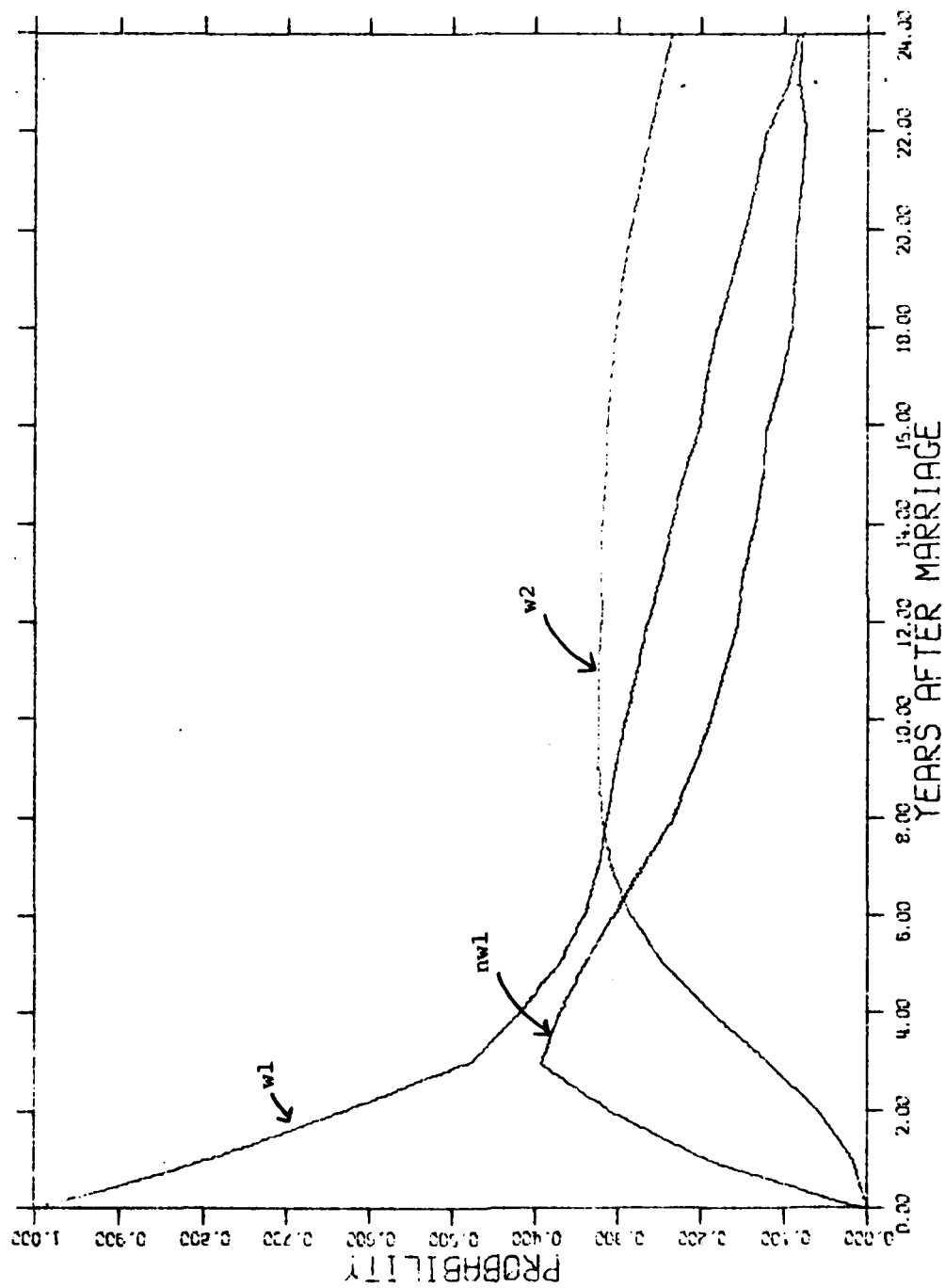


FIGURE 3

EDUC=16 YRS, RACE=WHITE

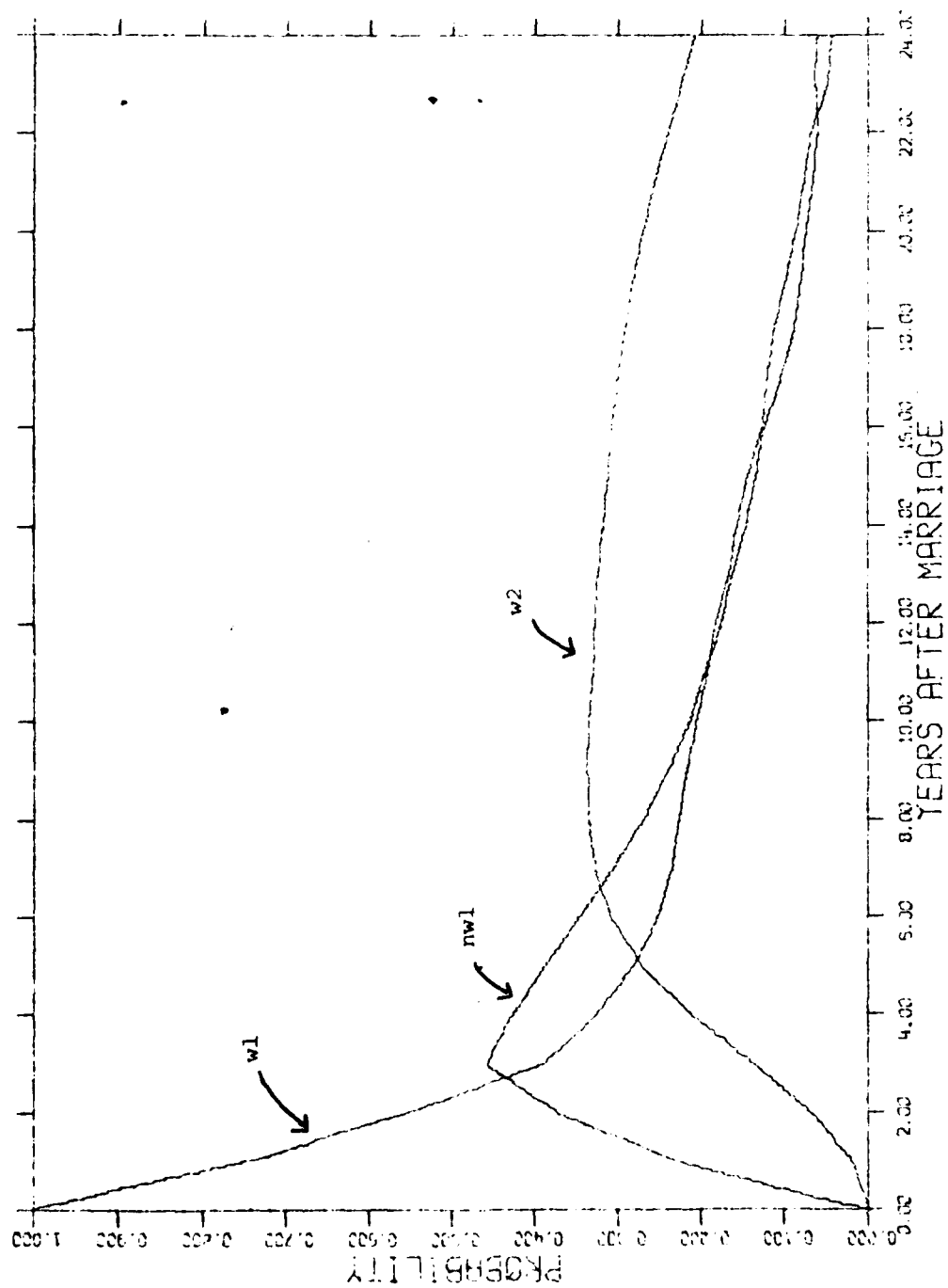
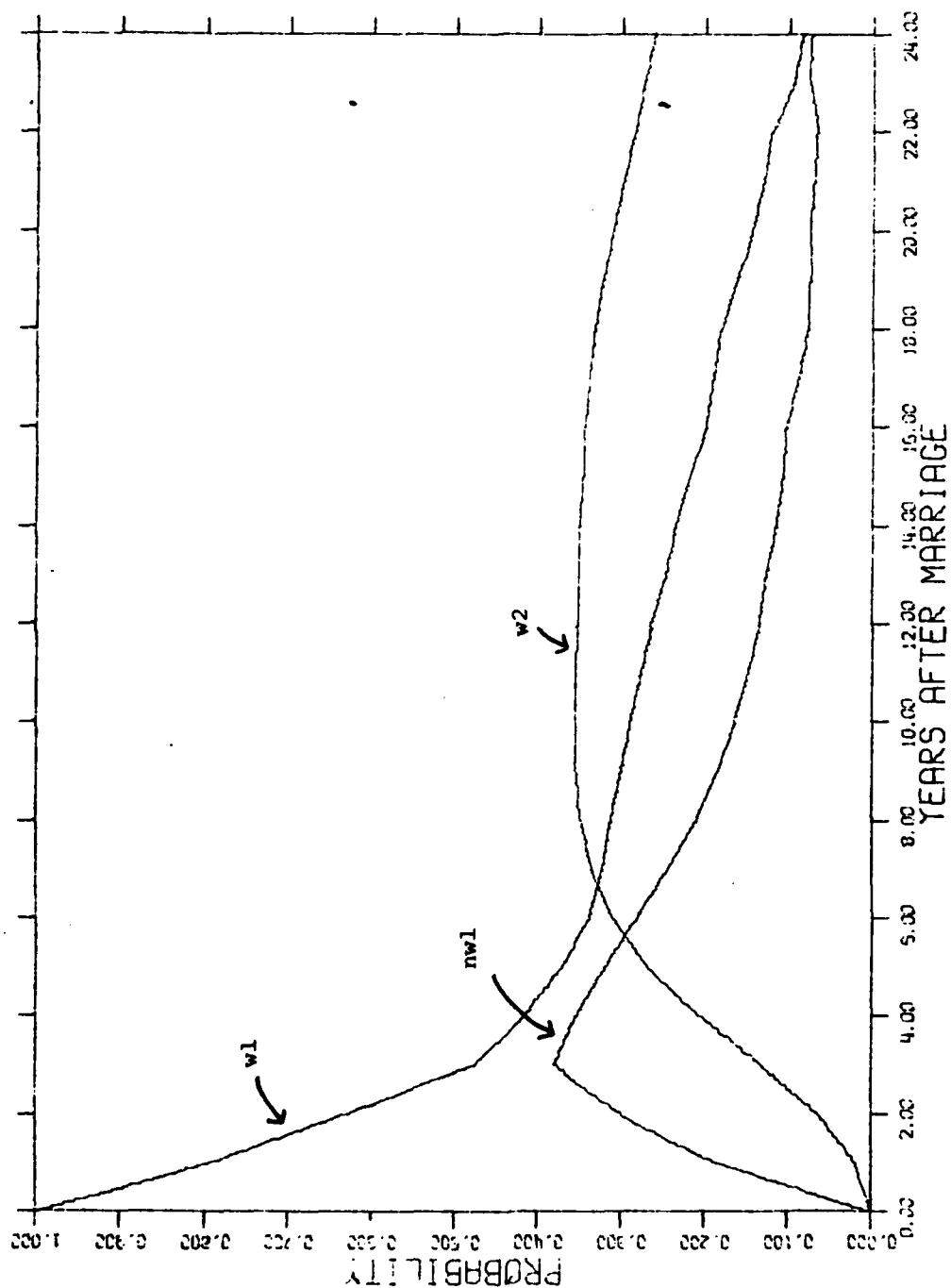


FIGURE 4

EDUC=16 YRS, RACE=BLACK



that the probability women are in state w2 (working for the second time since marriage) increases for the first eight years of marriage and level off thereafter. A similar interpretation holds for Figures 2 to 4.

The above analysis indicates that at any point in time nonwhite and highly educated married women are more likely to be participating in the labor force than white and lesser educated married women. This is consistent with the findings of Nelson [1977] and others who have used probit analysis to study the labor force participation decisions of married women. However, our model allows us to go one step further in the analysis. It tells us that nonwhite and educated married women remain in the labor force longer (once they enter) and remain out of the labor force shorter (once they leave) than white and lesser educated married women. We feel this is an important finding that has only been implied and not tested directly in previous papers. Hopefully our findings in this paper will be of some help to others who are studying multiple spell unemployment-employment data of married women.

#### IV. RELATING ENLISTMENT STANDARDS TO JOB PERFORMANCE: A SECOND ILLUSTRATION

In the previous illustration on the labor force participation decisions of married women, the matrix of transition probabilities did not have to be estimated. In this section we present an example where this matrix needs to be estimated. The example deals with the

advancement of first term Navy enlistees through the paygrades of the Navy.

The advancement model requires the estimation of two components of a recruit's service history. First, we must estimate the probabilities of subsequent transitions (advancement, reduction, or attrition) from any paygrade. Then, conditional on being in a particular paygrade, we must estimate the distribution of time spent in that paygrade until the next transition. Using the method described in section II, each of these quantities can be estimated while adjusting for the effects of recruit background characteristics. From the model we can then estimate the paygrade attainment probabilities as a function of time (i.e.,  $U_{ij}(t)$ ).

We estimated the paygrade attainment probabilities for four different combinations of recruit characteristics. These were

- o High school graduate, low mental test score (AFQT=70)
- o High school graduate, high mental test score (AFQT=90)
- o Non-high school graduate, low mental test score (AFQT=70)
- o Non-high school graduate, high mental test score (AFQT=90)

Figures 5-8 plot the paygrade attainment probabilities<sup>5</sup> for Electronic Technicians starting their service as an E-3. The graphs show that for high school graduates, recruits with a high mental test score advance only slightly faster than those with a low score. For non-high school graduates, there is practically no difference in advancement between the two mental test groups. These results serve to illustrate the usefulness of the method in section II.

## V. CONCLUSIONS

In this paper we derived a probability model that allows exogenous variables to have an impact on both the probability of changing states

<sup>5</sup>To graph these probabilities we had to estimate four Logit models and twelve Cox models. These estimates are available from the authors upon request.



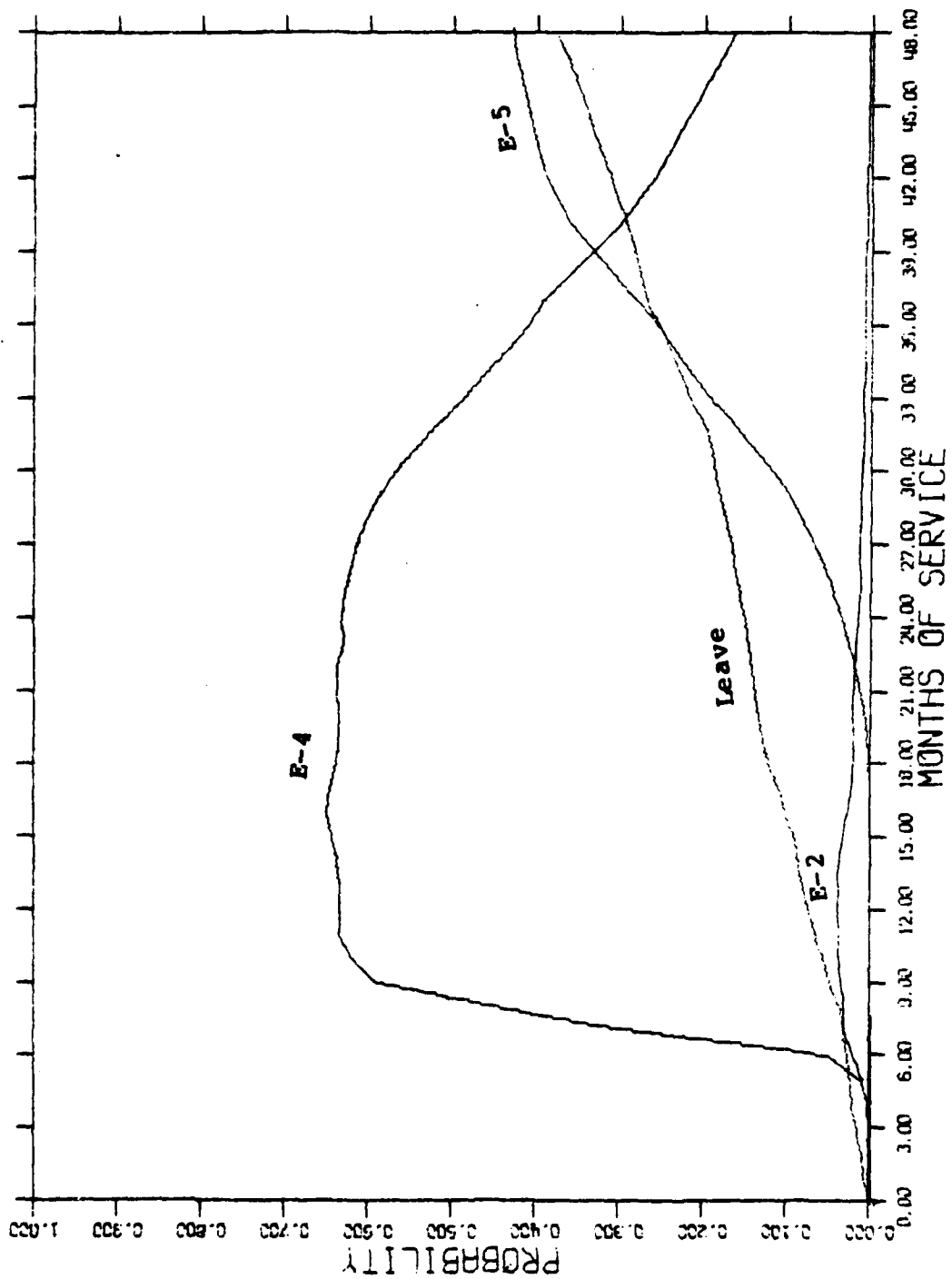


FIG. 5: SERVICE STATUS PROBABILITIES FOR ETNs: HSG, AFQT=70

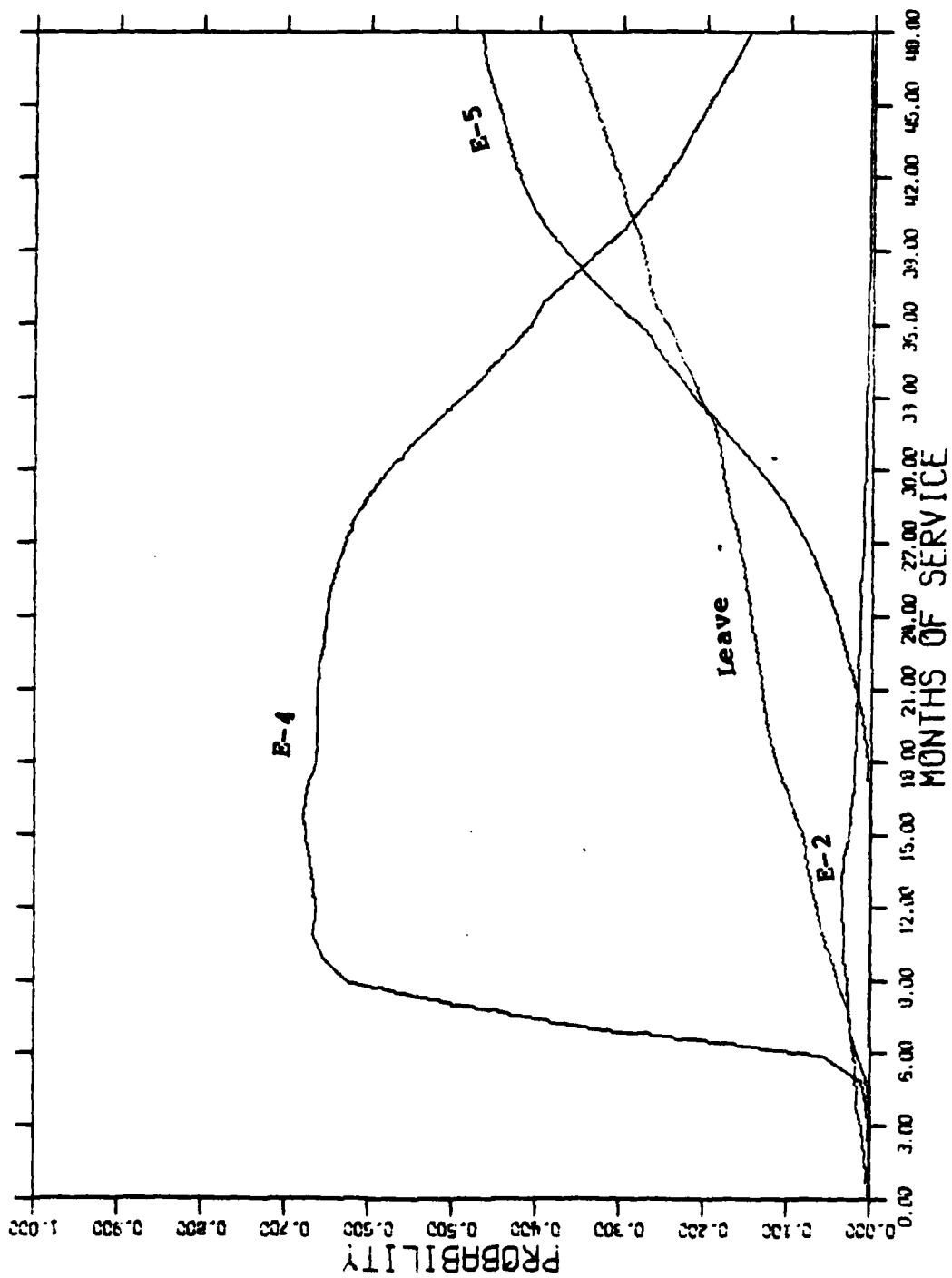


FIG. 6: SERVICE STATUS PROBABILITIES FOR ETNs: HSG, AFQT-90

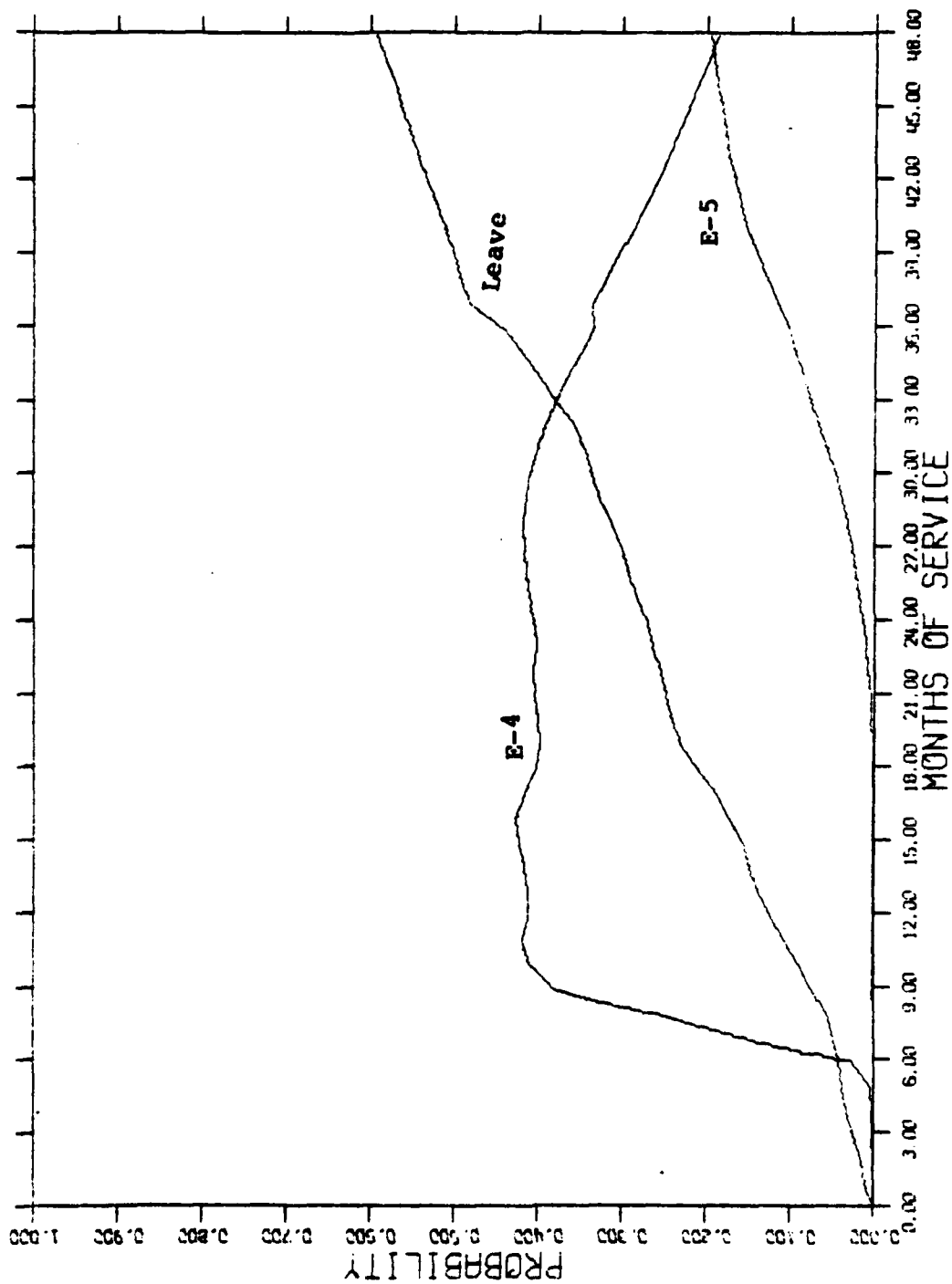


FIG. 7: SERVICE STATUS PROBABILITIES FOR ETNS: NHSG, AFQT=70

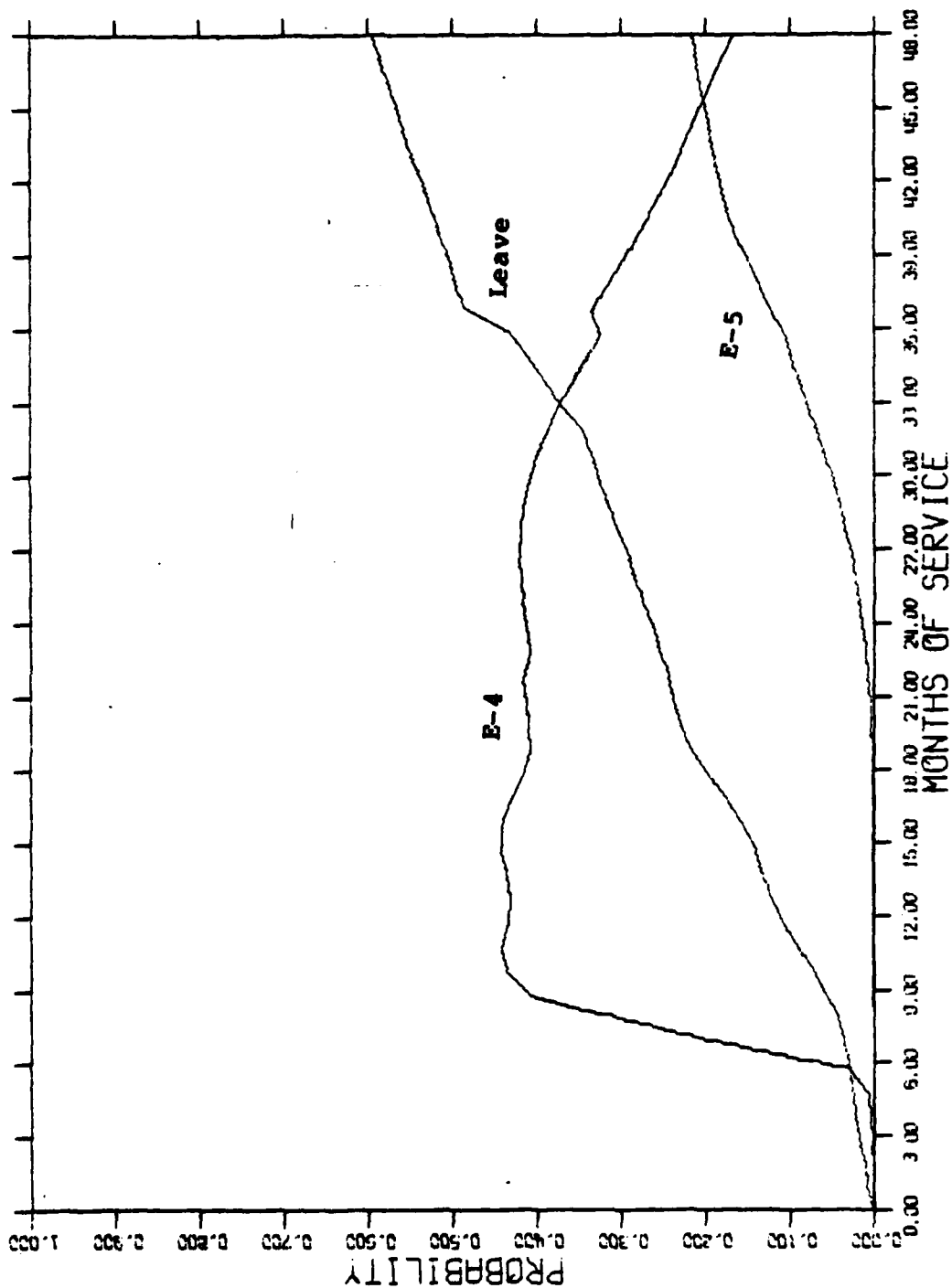


FIG. 8: SERVICE STATUS PROBABILITIES FOR ETNs: NHSG, AFQT=90

and on the length of time an individual remains in each state (duration). The probability of changing states is modeled with logit analysis and the time spent in each state is modeled with Cox regression analysis. Our proposed model is thus a hybrid of these two models. One important feature of our model is that it offers a simple method for analyzing multiple spell data.

We illustrate our model with two examples. In the first example we show how our model can be used to analyze multiple spell unemployment data. In the second example we show how the logit and Cox models are combined into a single probability model when the states are not ordered a priori.

Finally, we feel our model can be applied to several areas. For example, it could be used to study the fertility decisions of married couples or the promotional policies of various organizations. It is our hope that the model we present and apply here stimulates further research in these and other areas.

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